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APPLICATIONS OF GPS POSITIONING TO SPACE REMOTE SENSING

by

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1 OUTLINE

In the area of navigational positioning associated with various types of space craft, GPS application research is one key hot topic among people at present. Use is made of GPS receivers installed at fixed points on the ground and on space craft in order to precisely measure the positions of photographed spots in remote sensing imagery. In conjunction with this, these positioning data are used in area network combined average. As a result, it is possible to greatly reduce--even to eliminating--onerous measurement operations by outside industry.

In the air, in the analysis of triangulation, use is made of GPS data. It is possible to reach some kind of calculation accuracy and reliability. Inside China and abroad, scholars have carried out studies of this. Simulated calculation results are as below [1]:

1) GPS photo station point coordinates are extremely effective in area network combined average differences. It only requires medium accuracy GPS data and it is then possible to

* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

satisfy map making requirements at various types of scales (see Table 1).

Table 1 Combined Difference Precision Requirements on GPS

(1) 测图比例尺	(2) 摄影比例尺	等高距/m (3)	(4) 对GPS定位数据的要求/m	
			X, Y方向上的中误差 (5)	Z方向上的中误差 (6)
1:250000	1:500000	50	100	50
1:100000	1:100000	20	30	16
1:50000	1:70000	10	15	8
1:25000	1:50000	5	5	4
1:10000	1:30000	2	1.6	0.7

Photography Station Coordinates (1) Map Making Scale (2) Photograph Scale (3) Contour Interval/m (4) Requirements on GPS Positioning Data/m (5) Center Errors in X and Y Directions (6) Center Errors in Z Direction

2) Outside space, the utilization of azimuth line elements is generally more effective than the use of angular elements. The addition of attitude measurements, when their precision is very high, can be used in order to improve engineering accuracy.

3) Making use of GPS data light beam method zone net average differences, they will have relatively good reliability. This includes high reliability of GPS data itself as well as the reliability of small numbers of ground imagery control points, and so on. /39

4) Speaking in terms of basic principles, GPS supplied photo station point coordinates are capable of replacing ground earth control points used in zone net average differences. The conditions are that GPS data observed values must be continuous within photography zones and not have any breaks.

GPS navigational positioning technology and space flight remote sensing technology both currently two new high technologies with very bright prospects. There is mutual penetration and mutual combination between them, and they will bring to our remote sensing applied technology systems an earth shaking change, leading to the birth of a GPS remote sensing data geopositioning system.

2 BRIEF INTRODUCTION TO GPS REMOTE SENSING DATA GEOPOSITIONING SYSTEMS

The history of remote sensing is one of full speed development from ground remote sensing and aviation remote sensing to space flight remote sensing, from visible light to multiple spectra, and from square wave types to CCD scanning types. However, no matter whether it is the initial period of its development or the current stage of sensing technology. There are only two supporting pillars of the technology: qualitatively, what is the answer?; quantitatively, where is the answer, and what are the numerical quantities?

In these, the latter answer is in fact nothing else than the problem of remote sensing data geopositioning. Up to the present time, remote sensing data geopositioning methods have been primarily of the two types below:

1) Normal Transformation or So-Called "Air -> Ground" Type Transformation. Already having adequately accurate sensor positions and attitude data, use is made of simple transformation relationships to take sensing data and position it in corresponding ground coordinate systems.

2) Inverse Transformation. This is making use of ground control points to set up transformation relationships between imagery coordinate systems and ground control point coordinates. As far as current methods are concerned, they are to take sensing imagery and, on the basis of ground control points, force it into position on ground control grids.

The outstanding problem with inverse transformation methods is the need for ground geocontrol points. In one area, the measurement and setting up of these geocontrol points requires the expenditure of large amounts of manpower, materiel, and financial resources. Moreover, map compilation periods are long

(generally, 5 - 10 years for one renewal). This is not very well suited to the characteristics of speed, accuracy, and short periods possessed by remote sensing technology. In another area, satellite imagery used internationally in qualitative studies of the environment has already become a commercial product. Resolving problems of high precision positioning associated with remote sensing imagery becomes the key to our study of global environmental problems.

Remote sensing data geopositioning systems opting for the use of inverse transformation forms are the technological mainstay of current applied remote sensing data systems. We call them first generation remote sensing applied systems. Ten years from now, following further progress in penetration of GPS dynamic positioning technology into current remote sensing technology, a new generation of applied remote sensing systems will appear. It will possess the following 6 characteristics:

1) New models of data sources--such as, airborne and satellite borne synthetic aperture side scan radar imagery, multispectrum scanning instrument imagery, CCD new model sensor imagery and various types of data associated with broad DCS reception, forming multidimensional high capacity data sources.

2) Various types of expert systems using ecological earth science models, social economic models, remote sensing data characteristic models, specialty models, policy making models, and so on, as primary in their formation will gradually move toward practical use. In future, multi element, multidimensional analysis as well as comprehensive policy making will become the main trend in remote sensing data processing.

3) Geographical information systems (GIS) possessing analysis and resolution functions will achieve huge development. Data associated with remote sensing applications is entered

directly into GIS. Real time characteristics of GIS data are strengthened, making them finally turn into a remote sensing technology foundation and home base.

4) In order to adapt to the processing of high capacity data, intelligent models of computer system will gradually replace current imagery processing systems. Computer languages suited to the thought and decisions of human beings will achieve universal applications.

5) Conversion to high speed, multi function input and output systems is an inevitable trend in order to adapt to the requirements of a new generation of remote sensing application technology systems.

6) In 1993, if not delayed into 1994, the 24 satellites of the GPS global positioning system will all be launched into space. Various types of all time zone, all weather, continuous, fast, high precision GPS dynamic geopositioning technology systems can be introduced into broad applications. Corresponding technology links related to remote sensing data positioning will produce changes in direction characteristics.

The various characteristics above can be summarized as: qualitative accuracy, precise positioning, and fast multiple function quantitative inputs and outputs. Among these, GPS remote sensing geopositioning systems as well as such composite geopositioning systems as GPS/INS will cause position deviation terrain maps associated with remote sensing data to turn from "ground->air" inverse transformation type positioning modes into "air->ground" normal transformation type positioning modes, /40
realizing GPS geopositioning without ground control points. In conjunction with this, remote sensing data is directly taken to carry out earth science encoding to enter into GIS[2].

3 GPS SPACE FLIGHT REMOTE SENSING GEOPOSITIONING SYSTEMS

As far as space flight remote sensing geopositioning technology is concerned, it began with the U.S. making use of the Apollo space ship to carry out photo map making for the moon. In the 1970's, the U.S. launched natural resources satellites 1,2, and 3. Satellite positions were precisely measured by the use of satellite tracking network STRN and the later TDRSS system. On space shuttles, option is made for the use of inertial measurement equipment IMU to carry out positioning in orbit. The data goes through post processing and is capable of increasing precision. In attitude angle measurements, there are also differences. On LANDSAT 1,2,and 3, option is made for the use of gyroscope systems. On LANDSAT 4, inertial measurement systems are used carrying sidereal controls. On LANDSAT 5, option has already been made for GPS global positioning systems. It is possible to see that, in future, GPS will become a primary means of determining position in orbit. Precision of these systems are seen in Tables 2 and 3.

(1) (单位m)

(2) 系统	STRN		TDRSS			航天飞机		GPS
	(3) 实时	预报 (4)	(5) 实时	预报 (4)	后处理 (6)	(3) 实时	后处理 (6)	实时 (3)
(7) 沿轨道误差	110	260	430	610	75	1 000	300	10
(8) 垂直轨道误差	130	130	460	460	75	100	30	10
(9) 高度误差	130	150	90	90	50	100	30	15

Table 2 Space Positioning Precision of Various Systems (1) Unit (2) System (3) Real Time (4) Prediction (5) RealTime (6) Post Processing (7) Error Along Orbit (8) Perpendicular Orbit Error (9) Altitude Error

(1) 航天器	(2) 姿态测量系统	倾角 (3)	偏航角 (4)
LANDSAT 1,2,3	红外地平仪 (7)	0.01°	1.0°
LANDSAT 4	惯性加恒星 (8)	0.01°	0.01°
(5) 航天飞机	惯性测量设备 (9)	0.5°	0.5°
	安设调整误差装置 (10)	2°	2°
APOLLO	星相机 (11)	5″	5″
(6) 未来型号	光-电恒星系统 (12)	2″	2″

Table 3 Attitude Measurement Precision for Different Space Craft (1) Space Craft (2) Attitude Measurement System (3) Angle of Inclination (4) Angle of Drift (5) Space Shuttle (6) Future Models (7) Infrared Horizon Instruments (8) Inertial Plus Sidereal (9) Inertial Measurement Equipment (10) Installation Error Adjustment System (11) Sidereal Camera (12) Photoelectric Sidereal System

In order to achieve instantaneous photographic attitude angles, with regard to film photographic systems, using star cameras is relatively ideal. With regard to photoelectric photographic systems--due to attitudes associated with imagery instantaneous linear arrays all needing to be precisely determined--as a result, opting for the use of photoelectric star systems is necessary [3].

3.1 Geopositioning Associated with Recoverable Type Remote Sensing Satellite Imagery

Upon consideration, Chinese technology is relatively mature in the area of developing returnable type remote sensing satellites. It is proposed, first of all, on satellites in this type of application, to load GPS receivers on carrier satellites, to make use of C/A code to carry out tracking measurements on satellites, and to use orbital improvements and after the fact processing methods in order to realize onboard satellite orbit determinations. In this way, it is not only possible to obtain first hand satellite onboard data. It is also possible to improve the quality of remote sensing imagery geopositioning.

There are people who carry out calculations on near earth photographic satellites with altitudes of 300 km. When satellite course errors are ±100m, observation system errors are ±10m, and equivalent GPS satellite time difference errors are ±15m, it is possible to get real time orbital position accuracies of better than ±30m[4]. They improve on current methods by an order of magnitude, showing the enormous potential of GPS applications in space flight remote sensing.

3.2 Key Technology Links in Natural Disaster Real Time Space Monitoring Systems

China is a country with many natural disasters. Its national territory is vast. As a result, this occupies an important place with regard to natural disaster monitoring and evaluation in disaster prevention, disaster fighting, and disaster relief [5].

Speaking with regard to synthetic aperture radar imagery real time positioning as well as remote sensing data three dimensional measurement operations, whether or not real time GPS positioning data is acquired is key. Through digital /41 transmission systems, satellites not only take accurate disaster area positions and, following along with multiple source remote sensing data flows, send them directly to monitoring application system terminals. Moreover, they make originally very complicated microwave remote sensing imagery processing and geopositioning operations able to use relatively simple methods in order to do processing. Disaster status imagery is capable of throwing open terrain maps directly to geopositioning, processing out in a timely manner all the relevant disaster status data. Without doubt, opting for the use of GPS remote data positioning systems is a powerful measure to guarantee monitoring system capabilities to react rapidly and accurately.

Internationally, such countries as the U.S., Germany, and Holland all did a number of tests making use of airborne GPS receivers, obtaining satisfactory results. Within China, from July - November 1990, tests in the Beijing area by the "GPS Combined Experimental Research Team" organized from the Academy of Sciences Remote Sensing Institute No.5 clearly show that

single aircraft positioning accuracies achieved using airborne GPS receivers are such that center error in the X direction is 7.982 meters, center error in the Y direction is 7.451 meters, and center error in the Z direction is 2.725 meters[2]. The accuracies in question completely satisfy airborne disaster monitoring requirements (approximately on the order of 10m). It is possible to make direct applications to the positioning of weather satellite and disaster reduction satellite remote sensing imagery.

3.3 Technology Support Systems for Global Natural Resource and Environmental Research

Today, research on global natural resources and the environment has already become a hot topic. What space flight remote sensing imagery gives is information precisely specifying the nature and type of ground objects. This type of imagery information has already been realized as a commercial product. However, the foundation of statistics, calculations of quantities, and various types of digital indices associated with special project data still belong to the problems of how to accurately determine positions. On LANDSAT-5, GPS receivers are already installed. On the basis of reports, the positioning accuracies along orbits and perpendicular directions each have approximately 10m positioning errors. The error in the altitude direction is 15m.

Besides this, speaking in terms of GPS space flight remote sensing data geopositioning systems--with regard to current wars or future wars--they are also extremely important. Remote sensing data time effectiveness adequately embodies the superiority associated with "time is life".

4 SOME IDEAS ON THE DEVELOPMENT OF CHINESE GPS SPACE FLIGHT REMOTE SENSING GEOPOSITIONING SYSTEMS

4.1 Tracking International Development Levels, Take Them and Include Them in New National High Technology Development Projects

1) As far as GPS having to be applied to space flight remote sensing is concerned, the problems which must be solved first are problems of satellite borne receivers. On a firmly laid domestic foundation, we suggest broad development and lateral technology exchanges between nations, introducing small amounts of foreign equipment, and, on the basis of the national situation involved, study of applied developments of satellite borne receivers.

2) On the basis of points of similarity in signals between GPS, GLONASS, AND NAVSAT and clever handling of their points of difference, a type of universal satellite signal reception technology has been developed. In conjunction with that, efforts have been made to achieve compatibility with projected Chinese developments of satellite guidance positioning systems. In this way, not only are the risks brought by excessive dependence on one type of system reduced. Moreover, it establishes a Chinese high technology industry producing consumer equipment in series.

3) Accelerate construction of Chinese multi function GPS satellite ground tracking stations, supplying self-measured precision star courses, reducing the influence of U.S. GPS policies on China. Simulation calculations clearly show that, in China proper, a GPS satellite fixed orbit observation network

composed of 3 - 4 monitoring stations is adequate to reach a ±2m fixed orbit accuracy, thereby obtaining GPS operating satellite precision ephereris in order to satisfy Chinese users--in particular, the requirements of the broad masses of mobile users for positioning.

4) Strengthen research on GPS applications in space in order to adapt to the requirements of such areas as future remote sensing, communications, navigation, and so on, as well as strengthening capabilities to deal with various types of incidents which suddenly occur.

Following along with the rapid increase in the numbers of space craft launched by mankind and ceaseless increases in requirements for space positioning precision, that type of regional ground command and control network which has continued to be used over the last several decades is in the process of rapidly becoming obsolete. Moreover, it is not capable of /42 satisfying the requirements of 21st century space communications development. It must depend severely on the construction of global ground stations, and these ground stations are easily attacked and do not achieve safety and security. As a result, the U.S. is in the midst of studying a type of cooperative satellite system set up on a GPS foundation. If each satellite carries a GPS receiver to act as a part of the telemetry, tracking, and command subsystems, then, all space craft will be capable of maintaining precisely determined and credible time, ephereris, and direction estimates. Using this type of method, it is possible to make conventional operations simplify to become simply checking telemetry data. Under situations of data abnormality or sudden changes in space environment, one type of static mode will be initiated. Ground portions will begin anew to track the space craft in question.

5) As far as research to aggressively develop GPS and other sensor ports is concerned, it will produce even more ideal composite systems. GPS, besides being able to be utilized independently, also has a most striking advantage. This is nothing else than being able to link up (combine) with other sensors, expanding the performance to produce various types of even more ideal composite systems to bring into play maximum benefits--even to a point which was not imagined in the past--ensuring military and civilian use.

As far as GPS and other sensor combinations are concerned, they can take a great many forms. What Table 4 sets out is only a part of the applications in space flight remote sensing.

4.2 Research on Several Problems Influencing Positioning Precision

(1) Man Made Interference Problems Relating to GPS Signals

We know that the highs and lows in GPS broadcast ephemeris directly influence measurement precision for the positions of photo stations. With regard to GPS satellite ephemeris transmitted in C/A code, after the U.S. uses ϵ technology to do processing, the precision falls to approximately ±100m.

Table 4 Future Composite Modes

(1) 组合模式	(2) 结果与用途	(3) 备注
GPS+空间站 (4)	(6)综合对地观测系统	解决空间站自主定位，完成对地观测 (11)
GPS+CCD	(7)推扫式光-电摄影测量系统	代表未来空间遥感技术的发展方向 (12)
GPS+IRMSS	(8)多光谱资源普查	GPS为遥感图像提供高精度空间坐标 (13)
GPS+SAR	(9) 星载雷达摄影测量	全天时、全天候的空间监测系统 (14)
GPS+胶片型空间相机 (5)	(10)“无地面控制点”测图	缩短中小比例尺地图的成图周期 (15)

(1) Composite Mode (2) Results and Uses (3) Remarks (4) Space Station (5) Film Type Space Camera (6) Composite Earth Observation System (7) Scanning Type Photoelectric Photographic Measurement System (8) Multispectrum Natural Resource Survey (9) Satellite Borne Radar Photographic Measurements (10) "No Ground Control Point" Survey Map (11) Resolving Space Station Autonomous Positioning and Completing Earth Observations (12) Represents Development Trends in Future Space Remote Sensing Technology (13) GPS Is Remote Sensing Imagery Supplying High Precision Space Coordinates (14) All Climate, All Weather Space Monitoring System (15) Shortened Medium and Small Scale Map Making Periods

It is reported that GPS satellite datum signals (10.23 MHz) will also go through high frequency vibration technology treatment. From 16 March to 29 August 1990, the U.S. not only experiments on C/A code ephemeris precision drops. Moreover, they also did high frequency vibration tests on satellites. Speaking in terms of mobile users, if they are not able to effectively reject high frequency vibration signals, even if they opt for the use of carrier wave phase measurements, it is still difficult to obtain predicted high precision point position coordinates. With regard to C/A code ephemeris precision drops, we are still capable of opting for the use of real time and after the fact differential technologies to add an effective elimination.

(2) The Puzzle of Full Cycle Jumps

In static GPS positioning situations, at the present time, several types of detection and restoration methods have been found. However, in dynamic GPS positioning situations, at present, there is a lack of cycle jump restoration techniques. Generally, it is only an attempt to prevent the occurrence of cycle jump situations. Through great research concentration, the Wuhan Mapping Science and Technology College satellite measurement teaching and research section's Professor Liu Jiyu put forward the utilization of improved receiver measurement principles as a method of eliminating cycle jump, that is, "Mr. Liu's Step Method"[6].

(3) GPS Receiving Antenna Installation and Its Influences

In order to guarantee continuity of dynamic positioning, 2 or more receiving antennas are installed on flight craft for different visibility conditions. If 3 auxiliary antennas are installed, then, there is a possibility, at the same time as measuring photo station positions, to measure photo attitude

angles. /43

As far as installation of antennas on satellites is concerned, it not only requires selecting for use a place with a broad field of vision. Moreover, special attention must be paid to the influences of multiple path effects. It is possible to opt for the use of GPS antenna auxiliary ring shaped path control coil installation, and it is then possible to effectively restrain reflected waves coming from satellite surfaces. The U.S. preliminary JPL tests clearly showed that this type of method is capable of making single frequency P code average amplitude values for false distances associated with multiple path errors drop from 1 meter to the centimeter level.

Besides this, when GPS antennas are installed on satellites, one should strictly guard against series interference noise. In conjunction with this, guard against prepositioned amplifiers in antennas being "burned out".

4.3 Expanded Exchanges, Cooperative Tackling of Key Problems, Concentration of Force, The Fist Is Formed, Breakthroughs at Key Points

The processes of application, testing, and research on GPS in space flight remote sensing positioning are relatively complicated. Conditions are relatively numerous. They cannot be fulfilled with the power of a single department or a single system. A concerted attack on key problems by various departments is required. Only when the strengths of various departments and various disciplines are exerted is it possible to achieve success. Cross combinations between relevant units as well as strengthening disciplinary exchanges, cooperative divisions of labor, exerting the power of each respective specialty, avoiding blind introductions or low level repetitions,

carrying out breakthroughs at key points, and the improvement of application levels for Chinese dynamic GPS are suggested.

REFERENCES

1 李德仁.GPS全球定位系统在航空遥感精确定位中的应用.中国地理学会环境遥感分会90年代遥感发展趋势和前沿学术研讨会论文，北京，1991.

2 李树楷等.遥感应用技术系统的技术支柱.中国地理学会环境遥感分会90年代遥感发展趋势和前沿学术研讨会论文，北京，1991.

3 王任享.国外航天摄影定位与制图.军事测绘，1989（3）：38～41

4 徐建华.GPS在卫星摄影测量中的应用.解放军测绘学院学报，1988（2）：54～61

5 闵桂荣.我国应用卫星的状况与展望.中国空间科学技术，1990，10（2）：2～4

6 刘基余.GPS卫星定位在遥感技术中的应用问题.中国地理学会环境遥感分会90年代遥感发展趋势和前沿学术研讨会论文，北京，1991.

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